Early Endovascular Treatment of Superior Mesenteric Occlusion Secondary to Thromboemboli

Z. Jia [a], G. Jiang [a,*], F. Tian [a], J. Zhao [a], S. Li [a], K. Wang [a], Y. Wang [a], L. Jiang [a], W. Wang [b]

[a] Department of Interventional Radiography, The Second Hospital of Changzhou Affiliated to Nanjing Medical University, Jiangsu Province, China
[b] Imaging Institute, Section of Interventional Radiology, Cleveland Clinic, Cleveland, OH, USA

WHAT THIS PAPER ADDS

Acute thromboembolic occlusion of the superior mesenteric artery (SMA) is a life-threatening disease. Despite advances in surgical technique, mortality remains high. The results of our study indicate that percutaneous revascularization is a promising alternative to surgical reconstruction in selected patients who present with acute occlusion of the SMA.

Objective: To evaluate our early experience with endovascular revascularization in patients with acute thromboembolic occlusion of the superior mesenteric artery (SMA).

Methods: A retrospective review was conducted of all patients who underwent endovascular revascularization for acute thromboembolic SMA occlusion from May 2005 to May 2012. Endovascular revascularization was performed using aspiration, intra-arterial thrombolysis, and adjunctive stent-placement techniques. Laparotomy was performed if the patient developed clinical signs of advanced bowel ischemia after endovascular procedure.

Results: Twenty-one patients underwent endovascular revascularization for acute thromboembolic SMA occlusion. All presented with acute-onset abdominal pain. Three patients had rebound tenderness before the procedure. Computed tomography angiography revealed complete occlusion in seven cases and incomplete occlusion in 14 cases, with no evidence of free gas or bowel necrosis. The median duration from onset of symptoms to revascularization was 8.7 ± 4.1 hours (range, 2—18 hours). Completely successful endovascular revascularization occurred in six cases (aspiration alone, 3 cases; combined aspiration and urokinase, 3 cases); partial success was achieved in 15 cases (aspiration alone, 4 cases; combined aspiration and urokinase, 10 cases; and combined aspiration, urokinase, and stent placement, 1 case). Laparotomy was required in five patients, all of whom had SMA main trunk complete occlusion and required small bowel resection. The 30-day mortality for all patients was 9.5%. During a median follow-up of 26 months, 15 patients remained asymptomatic, three patients reported occasional abdominal pain, and one patient had temporary short-bowel syndrome.

Conclusions: Percutaneous revascularization is a promising alternative to surgery for acute SMA occlusion in selected patients who have no signs of advanced bowel ischemia. Early diagnosis followed by prompt endovascular intervention with close postprocedural monitoring is key. Laparotomy is indicated in patients who develop new or worsening signs of peritonism after endovascular procedure, particularly in those who had complete occlusion of the main trunk of the SMA.

Article history: Received 27 April 2013, Accepted 24 September 2013, Available online 2 October 2013

Keywords: Superior mesenteric artery, Embolus, Thrombus, Occlusion, Endovascular revascularization, Thrombolytic therapy

INTRODUCTION

Acute superior mesenteric artery (SMA) ischemia from thromboembolic occlusion is a life-threatening condition. Early diagnosis and prompt treatment are necessary to prevent bowel ischemia and subsequent bowel infarction, necrosis, or perforation.[1—5] Surgery is associated with a high rate of morbidity and mortality.[1,6,7] Endovascular techniques may be a better treatment option, as they carry a lower risk of morbidity; however, data supporting the use of these techniques are currently lacking.

The purpose of this study was to evaluate our early experience with an endovascular technique to re-establish perfusion to the bowel in patients who suffered from acute thromboembolic occlusion of the SMA.

* Corresponding author. G. Jiang, Department of Interventional Radiography, The Second Hospital of Changzhou Affiliated to Nanjing Medical University, Xing Long Road 29#, Chang Zhou, Jiangsu Province 213003, China.

E-mail address: 747094035@qq.com (G. Jiang).

1078-5884/$ — see front matter

http://dx.doi.org/10.1016/j.ejvs.2013.09.025

MATERIALS AND METHODS

Study design

This retrospective study was approved by our institutional review board. All patients who underwent endovascular revascularization for the treatment of acute thromboembolic occlusion of the SMA at our institution from May 2005 to May 2012 were included. Cases were identified through our departmental procedural log. Patient demographics, clinical information, and procedural data were gathered from patients' medical records.

Diagnostic workup

When acute SMA occlusion was suspected, patients underwent computed tomography angiography (CTA). Digital subtraction angiography (DSA) was then performed in those patients who were considered candidates for endovascular intervention. The findings of the CTA and DSA were used to assess the number and location of embolic occlusions.

Indications for endovascular revascularization

Endovascular revascularization was indicated when there was CTA evidence of acute occlusion of the SMA (either the main trunk or branch) and when there was no clinical or imaging evidence of advanced bowel ischemia. Patients therefore did not undergo endovascular intervention if they had abdominal rigidity, marked abdominal distension with scarce bowel sounds, hypovolemic or septic shock, abdominal free air, pneumatosis intestinalis, or air bubbles in the mesenteric veins on CT scan.

Techniques of endovascular revascularization

Conventional mesenteric arteriography was performed before endovascular therapy. A 5-Fr sheath was introduced through a femoral approach. A bolus of 3,000 to 5,000 units of heparin was immediately administered through the sheath, followed by 1,000 units per hour continuously during the procedure, with control of activated clotting time (target: approximately 200 seconds). The SMA was cannulated with a 5-Fr Cobra catheter, and selective superior mesenteric arteriography was performed in posterior-anterior and lateral projections. Once SMA occlusion was confirmed, the 5-Fr sheath was exchanged for an 8-Fr sheath. An 8-Fr guiding catheter (Vista Brite Tip Guiding Catheter, Johnson & Johnson Co. Ltd., Miami, FL, USA) was advanced through the 8-Fr sheath, with the curved tip placed at the orifice of the SMA. A 0.035-inch hydrophilic guide wire was then passed beyond the mesenteric occlusion. With the wire in place, a 6-Fr guiding catheter (Envoy Guiding Catheter, Johnson & Johnson Co. Ltd., New Brunswick, NJ, USA) was co-axially advanced through the 8-Fr guiding catheter past the occlusion. The guide wire was then removed, and thrombectomy was performed by aspirating through the 6-Fr guiding catheter with a 50-mL syringe while gradually pulling the guiding catheter out. This process was repeated multiple times as needed until the embolus was completely removed or further removal of the emboli was not possible. For disease in SMA branches, a 5-Fr catheter (Beacon Tip Torcon NB Advantage Catheter, Cook Co. Ltd., Bloomington, IN, USA) was used for aspiration.

Pharmacologic thrombolysis was indicated if there was inadequate contrast flow to the corresponding bowel because of residual thromboemboli. A 4-Fr infusion catheter (Uni*Fuse Infusion System, Angio Dynamics Co. Ltd., Latham, NY, USA) or a microcatheter (Progreat Microcatheter System, Terumo, Tokyo, Japan) was advanced just above the thromboembolic occlusion of the main trunk or branch, respectively, and a bolus of urokinase (e.g., 200,000 to 400,000 units) was slowly injected over 10 to 20 minutes. Direct intra-arterial administration of prostaglandin E1 was indicated when vascular spasm occurred. If residual luminal narrowing was greater than 75% because of underlying atherosclerosis, an adjunctive stent was placed.

Technical success of endovascular revascularization was defined as residual stenosis of the previously occluded artery of less than 30% in diameter, without migration of small thromboemboli to branches, along with prompt flow and visible contrast reaching the entire bowel. Partial success was defined as re-established or improved flow to the corresponding bowel but with residual luminal caliber greater than 30% or occurrence of small thromboemboli migration to distal vessels.[8,9]

Postprocedure care

After the endovascular procedure, all patients were admitted to the intensive care unit for close monitoring of potential worsening of mesenteric ischemia or complications from the procedure. All cases were managed with bowel rest, nasogastric drainage, intravenous fluid therapy, and nutritional support. Laparotomy was indicated if abdominal pain worsened or if the patient developed new symptoms or signs suggestive of bowel perforation and/or gangrene. If bowel perforation or gangrene was found during laparotomy, a bowel resection was performed. Relook laparotomy was performed if there was further clinical deterioration after bowel resection.

Subcutaneous low molecular weight heparin was administered routinely (low molecular weight heparin calcium injection, 0.1 mL/10 kg every 12 hours, GlaxoSmithKline Co. Ltd., London, UK) for 3 days. Warfarin was administered once the abdominal pain associated with bowel ischemia had resolved. Patients who had significant atherosclerotic disease (in the aorta and/or SMA) or who had received a metal stent were treated with antiplatelet therapy (oral clopidogrel 75 mg/day for 3 months and aspirin 100 mg/day for at least 1 year).

All patients who were treated with endovascular therapy underwent echocardiography to exclude a cardiac embolism.

Clinical follow-up

Outpatient clinic visits were offered at 1, 2, and 6 months during the first year and annually thereafter for follow-up of

abdominal pain (onset, duration, severity, and relation to meals) and other potential complications such as short-bowel syndrome (malabsorption, diarrhea, steatorrhea, fluid and electrolyte disturbances, and malnutrition). Patients who exhibited abdominal pain underwent CTA of the SMA. Telephone interviews were conducted if patients failed to return for a clinical visit.

RESULTS

From May 2005 to May 2012, a total of 28 patients presented to our emergency room with acute abdominal pain and were subsequently diagnosed with acute thromboembolic SMA occlusion. Of the 28 patients, 21 had no clinical or CT evidence of advanced bowel ischemia and were treated with endovascular techniques. The seven patients who were not treated with endovascular revascularization were excluded because of evidence of advanced bowel ischemia on physical examination, including abdominal rigidity on physical examination ($n = 7$); abdominal distension and scarce bowel sounds ($n = 4$); shock upon initial presentation ($n = 1$); intestinal expansion, gas, and fluid gathering ($n = 4$); and peritoneal effusion ($n = 3$). None of these patients had free air and pneumatosis intestinalis on CT.

Table 1 summarizes the clinical characteristics, treatments, and outcomes for the 21 patients who underwent percutaneous endovascular therapy. The patient group included 15 men and six women with a median age of 71 years (range, 54—87 years). The median duration from onset of symptoms to endovascular intervention was 8.7 ± 4.1 hours (range, 2—18 hours). Of the 21 patients, 15 (71.4%) had elevated neutrophils and 14 (66.7%) had elevated D-dimer on admission. A total of 15 (71.4%) patients had atrial fibrillation (AF); among these patients, 12 (80%) had received anticoagulant therapy, but only three of the 12 (25%) had achieved therapeutic levels with international normalized ratio on admission (range, 2.0—3.0). In the three patients with AF who did not receive anticoagulation therapy, one was found to have thrombus in the left atrium on echocardiography, and two had a history of peripheral arterial embolism (1.2 and 3 years before presentation). Echocardiography was performed in all 21 patients, and no evidence was found of atrial septal defect or ventricular septal defect.

All 21 cases demonstrated thromboembolic SMA occlusion on both CTA and DSA, and all patients had single vessel occlusion. There were 17 main trunk occlusions (5 complete and 12 incomplete) and four branch occlusions (2 complete and 2 incomplete) (Table 1). Complete technical success was achieved in six cases (28.6%); all of these were in the main trunk. Partial technical success was achieved in 15 cases (71.4%, Fig. 1); 11 of these were in the main trunk, and four were in branches. Aspiration alone was effective in seven cases, and additional thrombolysis was required in the remaining 14 patients. Prostaglandin E1 (10 μg) was administered intra-arterially in 17 cases. One patient with severe main trunk atherosclerotic stenosis also received a self-expandable stent (Acculink Carotid Stent System; Abbot Laboratories, Abbott Park, IL, USA). Despite these successful endovascular procedures, five patients (all with main SMA trunk complete occlusion) had to undergo laparotomy within 24 hours (8—24 hours), two for new tenderness and rebound, and three for worsening abdominal tenderness and rebound. Complete technical success had been achieved in one of these patients and partial technical success, in the remaining four. Small bowel resection was required in all cases because of necrosis. The average length of the resected bowel was 93 cm (range, 20—135 cm). A second-look laparotomy was performed in one patient at 34 hours, but no further bowel resection was required.

Clinical follow-up revealed a 30-day mortality rate of 9.5% (2 of 21 patients). One patient died of acute respiratory distress syndrome 2 days after the endovascular procedure, and another died of sepsis and acute renal failure 4 days after the procedure. Over a median follow-up of 26 months (range, 8—78 months), abdominal symptoms completely resolved in 15 patients. CTA was performed in three patients (2 of whom exhibited atherosclerosis of the SMA before the procedure) who presented with recurrent abdominal pain, and all of these patients were found to have moderate stenosis at the main trunk of the SMA. One patient who underwent laparotomy exhibited temporary short-bowel syndrome that resolved after 8 months. The patient in whom a stent was placed was symptom-free at 9 months. One patient had a cerebral infarction 12 months after the endovascular procedure. There was no recurrence of SMA occlusion in any of the patients over the follow-up period.

DISCUSSION

Acute thromboembolic occlusion of SMA is associated with a high rate of morbidity and mortality despite many improvements in the diagnosis and treatment of this condition.[1,6] Early diagnosis and immediate treatment are the most important factors in the attempt to reverse ischemia in the intestine.[7,10] Our study demonstrates that early endovascular therapy can lead to improved outcomes in patients with this condition, with 30-day mortality of 9.5%.

Clinical diagnosis of early SMA occlusion is difficult because of the lack of a specific presentation. A typical symptom is sudden-onset abdominal pain that is out of proportion on physical findings. All of the patients in our study presented with this type of abdominal pain. Another important diagnostic factor is serum D-dimer level, which has demonstrated high sensitivity for SMA occlusion.[11] In this study, 66.7% (14/21) of our cases had elevated D-dimer levels on admission. Similarly, Acosta et al.[12] reported that elevated serum troponin I (TnI) levels are frequently associated with acute SMA occlusion.

In patients at high risk for thromboembolic disease, with a history of AF, significant atherosclerotic disease, or peripheral arterial embolic disease, further evaluation is needed.[13] CTA allows for early diagnosis of thromboembolic occlusion of SMA and facilitates early intervention. Menke[14] reported that CT has a high sensitivity (93.3%) and specificity (95.9%) for the diagnosis of acute mesenteric

Table 1. Clinical characteristics, treatments, and outcomes of acute thromboembolic SMA occlusion in 21 patients.

No.	Age/ sex	Symptom	Atherosclerosis	Location	Occlusion	Onset (h)	Treatment	Technical success	TTL (h)	LBR (cm)	Follow-up	Outcome
1	77/M	AP	No atherosclerosis	Branch	>90%	5.5	Aspiration	Partial	No laparotomy	No bowel resection	78 mo	Completely recovered
2	59/M	AP	No atherosclerosis	Trunk	75–90%	8	Aspiration, thrombolysis	Partial	No laparotomy	No bowel resection	60 mo	Completely recovered
3	74/M	AP	Aorta	Branch	Complete	2	Aspiration	Partial	No laparotomy	No bowel resection	50 mo	Cerebral infarction after 12 mo
4	67/M	AP	No atherosclerosis	Trunk	>90%	3	Aspiration	Complete	No laparotomy	No bowel resection	50 mo	Completely recovered
5	76/F	AP	No atherosclerosis	Trunk	>90%	5	Aspiration, thrombolysis	Partial	No laparotomy	No bowel resection	48 mo	Occasional AP
6	69/M	AP	Aorta	Trunk	75–90%	9	Aspiration	Complete	No laparotomy	No bowel resection	43 mo	Completely recovered
7	81/M	AP	No atherosclerosis	Branch	>90%	14.5	Aspiration, thrombolysis	Partial	No laparotomy	No bowel resection	36 mo	Completely recovered
8	69/M	AP	No atherosclerosis	Trunk	Complete	10	Aspiration, thrombolysis, laparotomy	Complete	10	135	28 mo	Short bowel syndrome
9	74/F	AP	No atherosclerosis	Branch	Complete	8	Aspiration	Partial	No laparotomy	No bowel resection	28 mo	Completely recovered
10	59/M	AP	No atherosclerosis	Trunk	75–90%	16.5	Aspiration, thrombolysis	Complete	No laparotomy	No bowel resection	26 mo	Completely recovered
11	64/M	AP, ATR	No atherosclerosis	Trunk	Complete	10	Aspiration, thrombolysis, laparotomy	Partial	8	20	24 mo	Completely recovered
12	73/F	AP	No atherosclerosis	Trunk	75–90%	13	Aspiration, thrombolysis	Partial	No laparotomy	No bowel resection	24 mo	Completely recovered
13	87/M	AP	No atherosclerosis	Trunk	>90%	7	Aspiration	Partial	No laparotomy	No bowel resection	18 mo	Completely recovered
14	79/M	AP	No atherosclerosis	Trunk	Complete	9	Aspiration, thrombolysis, laparotomy	Partial	16	65	16 mo	Completely recovered
15	63/F	AP	No atherosclerosis	Trunk	75–90%	18	Aspiration, thrombolysis	Partial	No laparotomy	No bowel resection	14 mo	Completely recovered
16	76/M	AP, ATR	No atherosclerosis	Trunk	Complete	10.5	Aspiration, thrombolysis, laparotomy	Partial	24	130	2 d	Died
17	79/M	AP	No atherosclerosis	Trunk	75–90%	9.5	Aspiration, thrombolysis	Partial	No laparotomy	No bowel resection	14 mo	Completely recovered
18	68/M	AP	Aorta, SMA	Trunk	>90%	7	Aspiration	Complete	No laparotomy	No bowel resection	12 mo	Occasional AP
19	62/F	AP, ATR	No atherosclerosis	Trunk	Complete	9	Aspiration, thrombolysis, laparotomy	Partial	22	115	4 d	Died
20	54/M	AP	Aorta, SMA	Trunk	>90%	5.5	Aspiration, thrombolysis, stent	Partial	No laparotomy	No bowel resection	9 mo	Completely recovered
21	71/M	AP	Aorta, SMA	Trunk	>90%	2.5	Aspiration, thrombolysis	Complete	No laparotomy	No bowel resection	8 mo	Occasional AP

AP = abdominal pain; ATR = abdominal tenderness and rebound; d = day; LBR = length of bowel resection; mo = month; SMA = superior mesenteric artery; TTL = time to laparotomy.

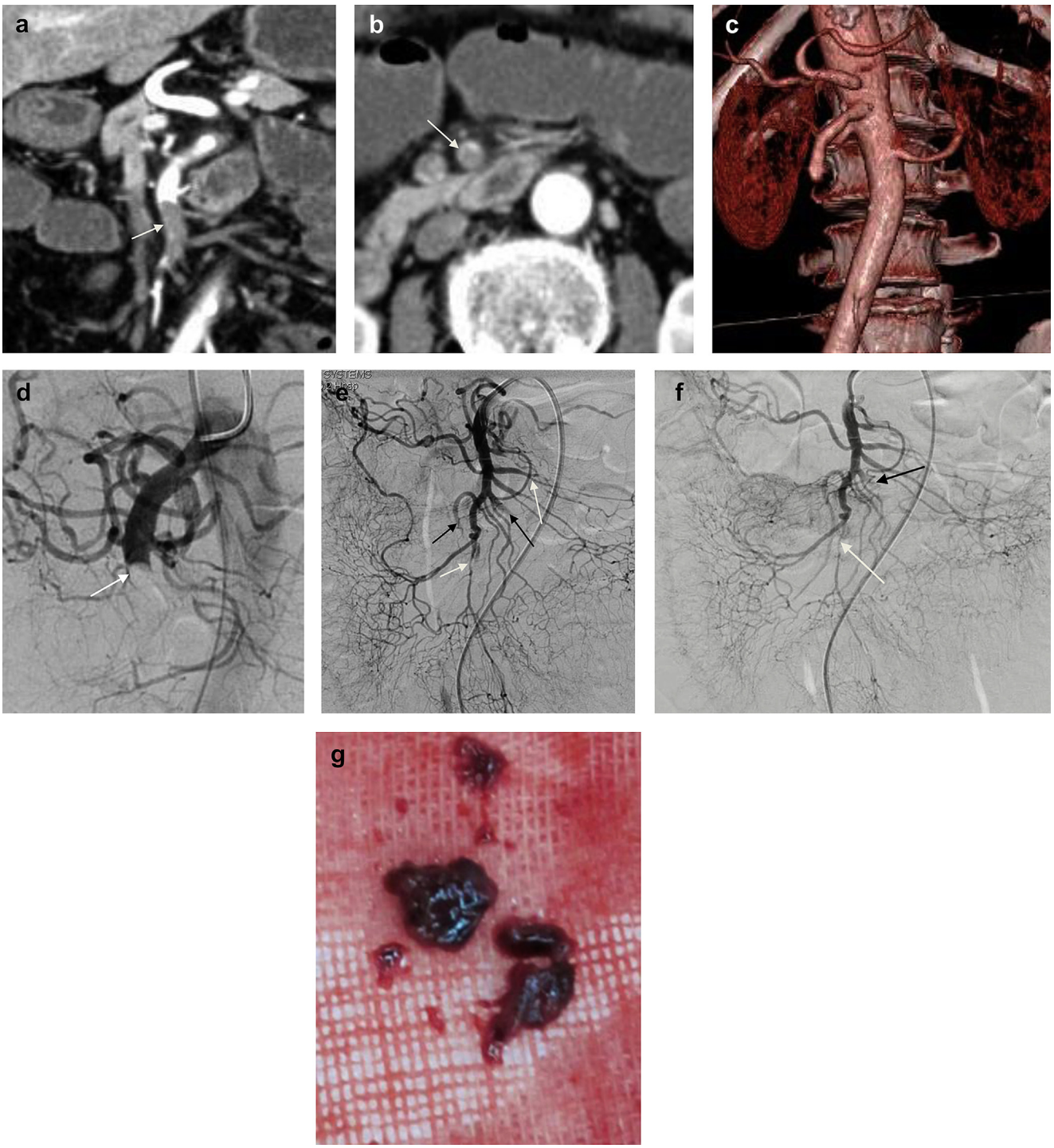

Figure 1. A 64-year-old man (case 11) presented with acute-onset abdominal pain that had begun 6 hours before presentation. (a) Computed tomography angiography (CTA) of the abdomen demonstrated abrupt occlusion of the superior mesenteric artery (SMA) 4.1 cm from the origin (arrow). (b) An axial image demonstrated a large central luminal filling defect with minimal contrast at the edge (arrow). (c) Volume-rendered CTA showed abrupt occlusion of the proximal SMA without collateral vessel. (d) Digital subtraction angiography (DSA) of the SMA revealed an occlusion with a conves meniscus, a typical sign for embolic occlusion (arrow). (e) After aspiration, the main trunk became patent, but small emboli (black arrows) and vasospasms (white arrows) were identified in the branches. (f) There was complete restoration of the flow to one branch (white arrow) and partial reopening to another (black arrow) after a bolus of urokinase (200,000 units) was slowly injected over 20 minutes, followed by an infusion of prostaglandin E1 (10 μg). (g) The aspirated thromboemboli can be seen.

ischemia, supporting the use of this technique as the first-line imaging method for suspected acute SMA occlusion. In our study, all patients had positive findings on CTA that were confirmed on selective arteriography. CT can also demonstrate any late complications of bowel ischemia. CTA is therefore the key study for diagnosing this condition and determining whether the patient is a candidate for an endovascular approach.

Surgery, including open embolectomy and direct evaluation of the viability of the gut with resection of any nonviable bowel, has been the traditional treatment for acute SMA occlusion. However, open surgery has a high mortality rate.[1,6] Furthermore, a satisfactory embolectomy result may not be possible with surgery in certain conditions, such as multiple or small branch emboli. Immediately after surgery, anticoagulant therapy is contraindicated because of concerns about bleeding, which plays an important role in the management of thrombotic disease.

Percutaneous revascularization may be an effective therapeutic alternative to surgical treatment in selected patients.[15] The main advantage of this technique is that it is less invasive, carrying a low rate of procedure-related mortality and morbidity.[16,17] Whereas previous research has demonstrated a surgical mortality rate of 59% (range, 31—78%),[1,6,7] patients in our study had a 30-day mortality rate of 9.5%. The morbidity rate was also low, with only one patient (4.8% [1/21]) exhibiting temporary short-bowel syndrome. Arthurs et al.[18] reported that endovascular therapy also results in lower laparotomy rates, significantly less amount of bowel resection in surgical exploration, and fewer complications caused by renal or pulmonary failure. Additionally, endovascular therapy may be safe and effective for cases of peripheral and segmental occlusions or severe atherosclerosis, conditions in which surgical revascularization may be challenging.[17] Heiss et al.[19] suggested that endovascular treatment of SMA occlusion with peritoneal signs but no signs of bowel wall perforation might also be an option if surgical revascularization of the SMA is deemed unsuitable because of associated comorbidities, or if surgery will be delayed because an operating room or surgeon is not available.

The drawback of percutaneous revascularization is that the viability of the bowel structure cannot be assessed, and delayed diagnosis of bowel necrosis may increase morbidity and mortality. Therefore, appropriate selection of patients is important so that therapy is not delayed in patients with necrotic bowel. Our study also demonstrated that technical success in re-establishing SMA flow may not necessarily prevent occurrences of irreversible bowel ischemia and subsequent sepsis, shock, or even death.

In this study, three patients had abdominal tenderness and rebound on physical examination before endovascular therapy, with no CT evidence of bowel perforation or necrosis; these patients required laparotomy because of worsening bowel ischemia even after successful endovascular revascularization. In addition, two patients developed new symptoms of advanced bowel ischemia after endovascular therapy. All five of these patients had complete occlusion at the main trunk, indicating that the irreversible bowel ischemia occurs more often in those patients with complete occlusion of SMA main trunk.

Acute SMA thromboembolic disease can be associated with age, severe atherosclerotic disease, and AF.[20—22] The occlusion can be caused by a single embolus or multiple emboli consisting of simple thrombosis, organized clot, or atherosclerotic plaque. We believe that aspiration should be attempted first to remove the embolus and re-establish vital flow to the small bowel regardless of the composition of the emboli. Pharmacologic thrombolysis can assist when mechanical embolectomy is incomplete if the emboli consist predominantly of thrombosis. Arthurs et al.[18] reported that endovascular results are not correlated with the etiology of thromboemboli or the location of occlusion, but complete occlusions appeared to have a lower success rate than partial occlusions, results which were confirmed in our study. It is our experience that removal of the thromboemboli at the SMA trunk with a 6-Fr guiding catheter is much easier than removal in the branch arteries with a 5-Fr catheter. Therefore, residual thromboemboli in the SMA branches were seen more frequently than in the main trunk after aspiration. Fortunately, because the marginal arteries provide essential collaterals to maintain sufficient blood flow distally, it is not absolutely necessary to achieve complete restoration of blood flow in the branches. Ryer et al.[23] reported that severe atherosclerosis can be used as a predictor for poor outcome after endovascular treatment, and this was confirmed in our study. In patients with severe atherosclerosis, SMA narrowing may be caused by the underlying plaques, and acute occlusion may result from reduced flow. Therefore, a self-expanding stent placement is most appropriate after thrombectomy and/or thrombolysis in these patients.

Yun et al.[6] reported a low bleeding risk when anticoagulation with low molecular weight heparin was initiated 2 to 3 days after surgery; patients could then be converted to an oral vitamin K antagonist. In our study, low molecular weight heparin was administered routinely for 3 days, with the option of switching to warfarin if abdominal pain had resolved. We believe that the presence of abdominal pain is an important indicator of ongoing bowel ischemia, suggesting that the patient may require surgery. If such pain is absent, oral warfarin can safely be initiated. Our suggested treatment algorithm for acute thromboembolic occlusion of the SMA is outlined in Fig. 2.

The major limitation of this study was its retrospective nature, which did not allow for direct comparison with other treatment strategies. The sample size was also relatively small, with selection bias in our study population. Most of the patients who presented with advanced signs and symptoms of bowel ischemia were excluded from this study because of concerns over delaying treatment. Finally, most of our patients had incomplete rather than complete occlusion, which may have contributed to the positive outcomes.

CONCLUSION

Percutaneous endovascular therapy is a promising alternative to surgical revascularization for the treatment of acute SMA occlusion in selected patients. Early diagnosis with CTA followed by immediate endovascular intervention is the key to positive outcomes in these patients. Close postprocedure monitoring is also necessary, with laparotomy performed early in patients who develop new or worsening signs of

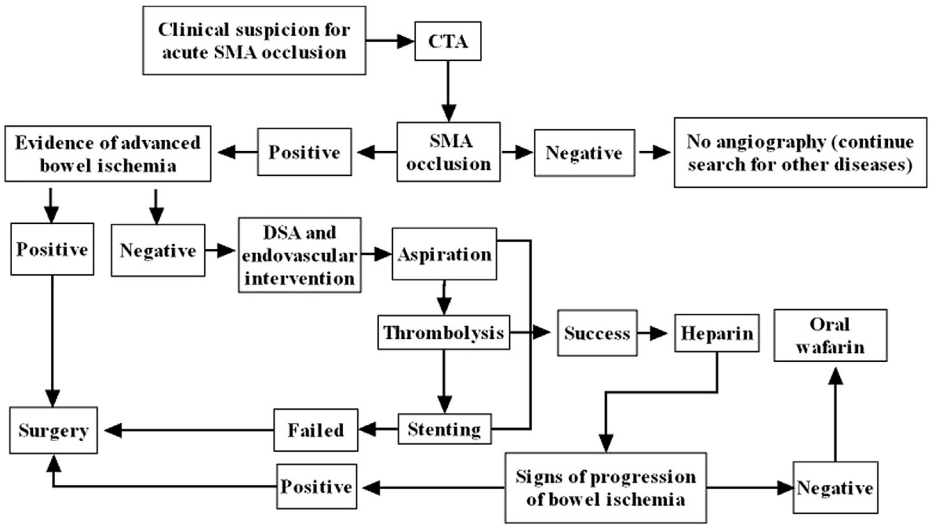

Figure 2. The treatment algorithm for acute thromboembolic occlusion of the SMA.

peritonism after the endovascular procedure, particularly in those who had complete occlusion of the main trunk of the SMA.

ACKNOWLEDGEMENT

We thank Matthew Tam, MD, for his advice in manuscript preparation and Megan Griffiths for her help with revising the manuscript.

CONFLICT OF INTEREST

None.

FUNDING

None.

REFERENCES

1 Eckstein HH. Acute mesenteric ischemia. Resection or reconstruction? *Chirurg* 2003;**74**(5):419—31.
2 Gore RM, Yaghmai V, Thakrar KH, Berlin JW, Mehta UK, Newmark GM, et al. Imaging in intestinal ischemic disorders. *Radiol Clin North Am* 2008;**46**(5):845—75 v.
3 Schoots IG, Levi MM, Reekers JA, Lameris JS, van Gulik TM. Thrombolytic therapy for acute superior mesenteric artery occlusion. *J Vasc Interv Radiol* 2005;**16**(3):317—29.
4 Debus ES, Diener H, Larena-Avellaneda A. Acute intestinal ischemia. *Chirurg* 2009;**80**(4):375—85 [quiz 86—7].
5 Romano S, Niola R, Maglione F, Romano L. Small bowel vascular disorders from arterial etiology and impaired venous drainage. *Radiol Clin North Am* 2008;**46**(5):891—908 vi.
6 Yun WS, Lee KK, Cho J, Kim HK, Huh S. Treatment outcome in patients with acute superior mesenteric artery embolism. *Ann Vasc Surg* 2013;**27**(5):613—20.
7 Newton 3rd WB, Sagransky MJ, Andrews JS, Hansen KJ, Corriere MA, Goodney PP, et al. Outcomes of revascularized acute mesenteric ischemia in the American College of Surgeons National Surgical Quality Improvement Program database. *Am Surg* 2011;**77**(7):832—8.
8 Kuo WT, Lee DE, Saad WE, Patel N, Sahler LG, Waldman DL. Superselective microcoil embolization for the treatment of lower gastrointestinal hemorrhage. *J Vasc Interv Radiol — JVIR* 2003;**14**(12):1503—9.
9 Funaki B. Microcatheter embolization of lower gastrointestinal hemorrhage: an old idea whose time has come. *Cardiovasc Intervent Radiol* 2004;**27**(6):591—9.
10 Chinsakchai K, Wongwanit C, Ruangsetakit C, Mutirangura P. Successful treatment in superior mesenteric artery embolism: a case report and literature review. *J Med Assoc Thai* 2010;**93**(6):739—44.
11 Acosta S, Bjorck M. Acute thrombo-embolic occlusion of the superior mesenteric artery: a prospective study in a well defined population. *Eur J Vasc Endovasc Surg* 2003;**26**(2):179—83.
12 Acosta S, Block T, Bjornsson S, Resch T, Bjorck M, Nilsson T. Diagnostic pitfalls at admission in patients with acute superior mesenteric artery occlusion. *J Emerg Med* 2012;**42**(6):635—41.
13 Paterno F, Longo WE. The etiology and pathogenesis of vascular disorders of the intestine. *Radiol Clin North Am* 2008;**46**(5):877—85 v.
14 Menke J. Diagnostic accuracy of multidetector CT in acute mesenteric ischemia: systematic review and meta-analysis. *Radiology* 2010;**256**(1):93—101.
15 Yilmaz S, Gurkan A, Erdogan O, Sindel T, Ceken K, Luleci E. Endovascular treatment of an acute superior mesenteric artery occlusion following failed surgical embolectomy. *J Endovasc Ther* 2003;**10**(2):386—91.
16 Falkensammer J, Oldenburg WA. Surgical and medical management of mesenteric ischemia. *Curr Treat Options Cardiovasc Med* 2006;**8**(2):137—43.
17 Acosta S, Sonesson B, Resch T. Endovascular therapeutic approaches for acute superior mesenteric artery occlusion. *Cardiovasc Intervent Radiol* 2009;**32**(5):896—905.
18 Arthurs ZM, Titus J, Bannazadeh M, Eagleton MJ, Srivastava S, Sarac TP, et al. A comparison of endovascular revascularization with traditional therapy for the treatment of acute mesenteric ischemia. *J Vasc Surg* 2011;**53**(3):698—704 [discussion 704—5].
19 Heiss P, Loewenhardt B, Manke C, Hellinger A, Dietl KH, Schlitt HJ, et al. Primary percutaneous aspiration and thrombolysis for the treatment of acute embolic superior mesenteric artery occlusion. *Eur Radiol* 2010;**20**(12):2948—58.

20 Lock G. Acute intestinal ischaemia. Best practice & research. *Clin Gastroenterol* 2001;**15**(1):83—98.
21 Wyers MC. Acute mesenteric ischemia: diagnostic approach and surgical treatment. *Semin Vasc Surg* 2010;**23**(1):9—20.
22 Acosta S, Ogren M, Sternby NH, Bergqvist D, Bjorck M. Incidence of acute thrombo-embolic occlusion of the superior mesenteric artery — a population-based study. *Eur J Vasc Endovasc Surg* 2004;**27**(2):145—50.
23 Ryer EJ, Kalra M, Oderich GS, Duncan AA, Gloviczki P, Cha S, et al. Revascularization for acute mesenteric ischemia. *J Vasc Surg* 2012;**55**(6):1682—9.